No. XIX.

CAST-IRON TRUSSES OR CRADLES FOR SUSTAINING DECAYED OR SUNKEN TIMBERS.

The LARGE GOLD MEDAL was this session presented to Mr. ALFRED AINGER, for various CAST-IRON TRUSSES or CRADLES, adapted to the support and preservation of partially decayed and sunken beams, girders, or other large timbers. The following communication has been received from him, and models of the inventions have been placed in the Society's repository.

22, Everett-street, Russell-square,
January 20, 1824.

DEAR SIR,

I HEREWITH offer to the Society models and drawings of various cast-iron trusses or cradles designed for the purpose of supporting girders, tie-beams, or other timbers whose ends have become decayed; and also for raising and sustaining bearers of any sort which have sunk in the middle. Before describing any of these particularly I will detail the circumstances which led to their invention, and to the successful application of one of them in a case of considerable difficulty.

During the repairs performed in the past year to the church of St. Mary Aldermary in the city of London, one of those erected by Sir Christopher Wren, it was discovered that nearly all the timbers of the roofs or flats over the aisles had become infected with the dry-rot, some of them

so much decayed by it as to have lost all bearing on the walls, and to have suffered a partial decomposition through their whole length. Their removal would have involved the destruction of a highly enriched, groined, and pannelled cieling, whose restoration would have cost probably five thousand pounds, and the ribs and cradling of which (themselves in some parts almost perished,) were immediately suspended from the decayed and decaying beams.

To secure these beams therefore, not merely without removal, but with as little cutting and violence as possible, became an object of considerable importance. To have bolted pieces of timber to their sides, as is commonly practised, would have been altogether useless, for, by that plan, the weight is made to rest on a bearing equal only to the size of the bolts, which would have cut through or crushed the fibreless and disintegrated matter to which the ends of the beams had become reduced. Independently of which, it is evident that the support afforded by one piece of timber bolted to the side of another depends on the resistance offered by each of them to opening or splitting in a line with one or more of the bolts which pierce them, and that they have to oppose the mere cohesion of their fibres to the operation of a powerful leverage; that cohesion is in the first instance uncertain and inadequate, and it becomes every day more so by the progress of the disease in the old timber, and by its inevitable communication to the new.

The use of wood, therefore, was rejected, and the application of iron determined on. The number of beams in the condition described was fifteen, making of course thirty ends which required securing. Economy dictated the use of cast-iron in a case where so many similar parts would be wanted, and it only remained to dispose the metal in such

a form as should make the smallest possible quantity produce the required effect, and should at the same time afford the greatest facilities in fixing. The form described in the models and drawings seems obviously to answer these conditions: it was adopted, and the plan carried successfully into execution with a degree of rapidity and ease which was in some measure surprising even to myself, and without the slightest injury to the cieling*.

That part of the roof which covered the nave, and which was composed of principal rafters and tie-beams framed with king-posts in the usual manner, was comparatively sound, but, nevertheless, decayed to a greater or less extent at all the bearings on the walls. In the former case it was required merely to support the ends of a simple bearer or girder, pressing perpendicularly by its own weight and that of its load; a task much easier than that of receiving the weight of the horizontal beam with its load, and at the same time opposing the lateral thrust of the rafter loaded with two or three tons of timber and lead, increased to four or six tons by reason of its inclined direction. I send a model of a design which I made for this purpose, but which, from various causes, was never executed. Among these causes, however, must not be placed any doubt of its success or of its economy, because, from the experiments made with the model, it appears to be perfectly easy in its application and effectual in accomplishing its object†.

* The details of the mode of fixing, expenses, and other particulars, are given in the description of the engravings.

† This also will be found more particularly described in the references to the engravings.

Together with these I send a model of a plan for quickly and cheaply raising and sustaining swagged or sunken girders, with the least possible disturbance of the floor, and without any injury to the cieling below it *.

I am, dear Sir,

&c. &c. &c.

A. Aikin, Esq.
Secretary, &c. &c.

ALFRED AINGER.

Reference to the engravings.—Plate XVII.

FIG. 1 is a side, fig. 2 an end, and fig. 3 a top or bird's-eye view of the truss first alluded to, exactly as it was applied. In each figure *a* is the wall plate, the beam being shown wholly unsupported by it, as was the case with several of those to which the trusses were fixed. The trusses or cradles consist of two equal and similar cast-iron side pieces, each composed of two triangles, *b c d e*, spreading at the feet *b*, to rest on the wall plate, and each having three ears *c c′*, *d d′*, and *e e′*, pierced to receive the wrought-iron bolts which unite each pair together. The bolts, of which one is shown separately at *f* fig. 4, were made with a head at one end and a slit at the other, to receive a key, (see *g*, fig. 4). Between the bolts and the timber were introduced cast-iron plates, their length equal to the width of the timber, and their breadth six inches: one of these is described at *h* and *i* fig. 4, showing the groove which received the edge of the bolt *f*. The operation of fixing was as follows:—A temporary support was given to the

* A description of this is added to that of the other engravings.

beam; so much of the rotten timber as seemed advisable was cut away; the wall plate, which had decayed, was exchanged for a new one; and one man being placed on each side of the beam, the two halves of the truss were at the same moment rested on the wall plate and supported at the other extremities by one hand of each man, while, with the hand at liberty, one man passed the bolt through the the ear *d′*, and it was guided through that at *d* by the remaining unemployed hand, which also introduced the key. The weight of the trusses being thus supported, they were left suspended by the bolt at *d d′*, while one man took one of the grooved plates *h*, fig. 4, and held it against the underside of the beam at *e*, till the bolt could be passed through by the other. This bolt being also keyed, the ends *d d′*, were lifted till the plate at *e* pressed against the beam, (from which it would be distant in the first instance about half an inch,) a grooved plate was then put under the bolt at *d*, the keys were slightly tightened to give connection to the whole, and two pairs of oak wedges *k k* and *l l*, were driven under the plate at *d*, by which of course the bolt and plate at *e* were made to *bite* against the beam, and the feet of the trusses were thrown with great force upon the wall plate. By using two pairs of wedges each foot was made to take a bearing independently of any irregularities in the wall plate or in the shape of the beam. A similar bolt, plate, and wedges, were applied at *c*, but these were merely to give stability and connection to the several parts, as they evidently support no part of the weight. The feet of the trusses had notches on their edges, in which spikes were driven to restore the usual connection between the timber and the wall. The whole operation of fixing (excluding of course the time employed in supporting the

beam, exchanging the wall plate, and so on,) occupied, as may be imagined, not more than ten or fifteen minutes, nor did it occasion the slightest disturbance either to the ribs or plastering of the appended groining and pannels.

The principle upon which this truss is constructed is evidently that of converting a transverse strain upon a certain quantity of metal into two other strains, each acting upon half the quantity, nearly in the direction of the length, one having a tendency to crush or bend, and the other to rend the metal: the two upper limbs, *b c* and *c d*, are in this case exposed to the former, and the two lower ones, *b e* and *e d*, to the latter. To make the truss, therefore, theoretically perfect, it would require that the strength of the upper and lower limbs should have an accurate relation to the different offices they perform. The liability to compression is small compared with that to extension, but the latter may, in some cases, be less than the liability to bend; this last, in fact, is so uncertain as to defy any very nice applications of theoretical strength, while the tension, and consequently the required size, of the lower limbs may be ascertained with great precision. The tension on the limb *b e*, for instance, and on the similar limb on the other side of the timber, may, with sufficient accuracy for all practical purposes, be resolved into a case of the bent lever, in which *b e* may be considered one arm, *e c* the other, and *b* the point at which the power is applied, (the power being half the weight of the beam and its load, when the load is equally distributed). If, therefore, 10 represent the arm *c e*, and 25 the arm *b e*, which were about the actual lengths in inches, measuring from the intersections of the centres of the limbs; if, also, W express

the whole weight of the beam and its load, then putting $\frac{W}{2}$ for the power, the direct strain on the two limbs is $\frac{25}{10} \times \frac{W}{2} = 1.25\ W$, or one and a quarter times the whole load. The tension then, on each, is ,625 W; and if F measure the cohesive force of a square inch of the material in the same terms (pounds for instance) as those in which W indicates the weight of the load, the required area of section for each of the lower limbs will be expressed in inches by $\frac{,625\ W}{F}$.

The calculated size for the lower limbs will generally be found sufficient for the upper ones, and as the metal cools better in uniform bars than in others, it will seldom be advisable to make any difference.

In this particular case the section of each limb was a parallelogram, two inches by one inch, having the two external angles truncated or reduced till it approached to a triangle, and till the area was 1.6 inches. In an experiment made for the purpose of assuring the safety of the trusses, they were applied to a new piece of timber twelve inches by ten inches, their feet resting on bearers twenty-one feet asunder. The beam was about twenty feet long, consequently clear of the bearers at each end, and it was loaded gradually with somewhat more than six tons. It was by that time considerably bent, and as the load was much larger than that which the actual beams could ever have to sustain, it was useless to pursue the experiment farther. The ends remained perfectly unaltered, and thus assured the efficacy of the trusses to the amount of six tons.

It has been shown before that the tension on the limb *b e*, and on the corresponding limb on the other side, is equal to one and a quarter times the whole load, equal therefore, in this experiment, to seven and a half tons. But as two cast-iron bars, having each a sectional area of 1.6 inches, will sustain upwards of twenty-two tons, the load might have been increased to somewhat more than $\frac{22}{1.25}$ or eighteen tons. This would, however, be approaching too nearly the breaking point for practice. One half the weight that would produce fracture is generally considered the largest load to which any material should be permanently exposed. One half, therefore, of eighteen tons is the greatest weight that these trusses should constantly bear. It is almost needless to add that their strength may be increased, as circumstances require, without limit.

The size of the ears will of course require no less consideration than that of the limbs. Those at *e* sustain the greatest weight, which may be thus ascertained:—suppose the two limbs *b e* and *c d* to form one lever, *d* being the fulcrum, *b* the place of the power, and *e* that of the weight. The power, as already shown, is half the whole load, or $\frac{w}{2}$; the limb *b e* was twenty-five inches, and *c d* twenty inches, the whole length of the lever therefore forty-five inches, and the pressure on the ears at *e* equal to $\frac{45}{20} \times \frac{w}{2}$, or 1.125 w, being somewhat less than that which the limbs *b e* receive. But as the ears are more exposed to sudden shocks, especially in fixing, they should be made

at least equal to the limb; and in this case they were so, being made as much wider than the limb as the width of the bolt-hole, that is to say they were two and a half inches wide, and pierced with a hole half an inch wide. The quantity of metal below the bolt was one and a half times that on each side.

The bolts were two inches by half an inch; and the bottom of the groove in the plates being made rather hollow from end to end, caused the bolts to rest only at the extreme edges of the plates, and gave to them all the strength of which they were susceptible.

As in most of the cases to which these trusses would be applicable it is requisite that they should not occupy a space much greater than the depth of the timber itself; in all these the cast-iron grooved plate and the bolt may be advantageously exchanged for a wrought-iron plate terminating in a screw bolt at each end, and the plate may be cut into the surface of the timber as much as circumstances render necessary. This will be understood by the description of the other trusses in which such plates are introduced.

It has been objected, and perhaps may again be so, that the oak wedges are liable to become infected by the rot and to decay. It would be a very short answer, and one involving no difficulty nor much expense, to say—use iron: but the fact is that iron would give no advantage to counterbalance the convenient facility with which wooden wedges are made to accommodate themselves to irregularities in the size or surface of the timber. It will be observed that there are no wedges at *e*, those at *c* are not at all concerned in supporting the weight, and those at *d* are so far removed from the seat of the disorder that before it could materially affect them the beam must drop from its rottenness at *e*.

Farther than this: as the wedges should be of new good oak it is hardly possible that they should become worse or even so bad as that part of the beam immediately under them; still less likely are they to become so bad as the timber of the beam at *e*, which receives a pressure more than double that to which the wedges are exposed.

All this, however, would be no argument for the use of pieces of oak bolted to the sides of the beams, because the ends of those pieces next to the wall would inevitably receive the infection; and as the support they give depends on the adhesion of their fibres even to the extremity, they immediately begin to lose strength. Besides which, the destruction of the lateral cohesion and tenacity of the fibre is the first effect of the dry-rot, and takes place long before the wood has lost the power of supporting a considerable weight pressing on its surface.

In regard to expense the advantage is greatly in favour of the iron; the whole weight of cast-iron at each end was one hundred and twenty-six pounds, and of wrought-iron twelve pounds. The cast-iron was supplied at fourteen shillings per cwt., and the wrought-iron at sixpence per pound. The expense of fixing, as has already been stated, is scarcely appreciable. If this be compared with the value of two pieces of oak, each six feet long, twelve inches deep, and four inches thick, together with three or four screw-bolts weighing nine or ten pounds each; and if to this be added the difficulty and risk of boring bolt-holes in timber so situated, the difference will be found to be in the ratio of not less than two to one.

Figs. 5 and 6, of the same plate, are a side and end view of the truss or cradle designed for the principal rafters and tie-beams. In this truss there is a peculiarity arising from

the circumstance that the width or thickness of the rafter is generally less than that of the tie-beam, as shown in fig. 6, and this requires that the limbs of the truss should not form straight lines, but that, in passing from the tie-beams on to the rafter, each should deviate half the difference of thickness of these two: that deviation is made where the bolts *n* and *o* pass through, in order that no loss of strength may be occasioned. The tie-beam rests upon a large wrought-iron plate, terminated at each end in a screw-bolt, as was suggested in reference to the former case, thus saving the depth occupied by detaching the bolt from the plate. The edges, *r r*, of the trusses are made thicker on the inner faces, and are cut into the sides of the rafter, as shown at fig. 7. At *q* there is a cast-iron plate, and a bolt with wedges similar to those before described, the tightening of which brings the plate *p* against the underside of the tie-beam. The action of the truss is as follows:—the perpendicular weight is sustained on the same principle as in the first case, by the two opposing pressures at *p* and *q*, through the intervention of the strut *m*, which is introduced for the purpose; the lateral thrust is resisted by the edges *r r*, cut into the sides of the rafters; and less directly, but more powerfully, by the bolt, plate, and wedges at *q*, as may be understood by considering that any tendency to lateral motion in that part of the rafter at *q* must describe a circle, having the strut *m* for radius and its lower end for a centre; the inclination of *m* from the perpendicular gives, therefore, to the rafter a tendency to move somewhat upwards in opposition to the bolt, plate, and wedges at *q*, and of consequence to the whole weight of the roof acting on the plate *p*; the two pressures, therefore, one arising from the actual weight of the rafter and

its load, the other from its lateral thrust, are made to oppose and to annihilate each other as far as any tendency to derange the parts of the framing is concerned, and the whole is reduced to a simple perpendicular action on the wall through the feet of the truss. A cast-iron plate and wedges are put under the bolt at *o*, which has the effect of tightening the whole and of supporting the tie-beam, if it should ever be required temporarily to remove the rafters. The bolt *n* is merely for connection with the rafter, and for maintaining the strength of the truss where it deviates from the straight line: *y y*, in fig. 5, is the line of section in fig. 6, and *z z* in that of fig. 7.

The same principles of calculation as those applied in the last case will determine the requisite strength of the several parts, and the saving of expense, as compared with any possible way of accomplishing the same object by oak blocks bolted to the timbers will be found to be in a still greater ratio; probably as three or four to one.

Figs. 8 and 9, of the same plate, describe a mode of raising and sustaining a sunken or broken girder, requiring the exposure of not more than four or five feet of the upper surface, and not at all disturbing the cieling. The cast-iron truss consists of two similar pieces, each composed of two triangles and a square or parallelogram, the lower part of which supports a wrought-iron plate, with two screws at each end, (shown separately at *s s*). Two smaller plates with screws bear on the top of the girder at *t* and *u*. The underside of the girder is notched to admit the plate *s s*, and it may be partially cut through at the top, then driving wedges between the plate *s s* and the timber, the centre of the girder will be raised to any required height, and will remain so.

A. AINGER.